

APPENDIX D

NOTATION

Symbol	Description
c	Unit soil cohesion, ksf; distance from centroid to outer fiber, ft
c_{st}	Distance from centroid of steel reinforcing rod to outer fiber, ft
c'	Effective unit soil cohesion, kips per square foot (ksf)
c_a	Adhesion of soil to base $\leq c$, ksf
d_r	Diameter of vane rod, inch
d_v	Vane diameter, inch
e	Void ratio
e_{max}	Reference void ratio of a soil at the minimum density
e_{min}	Reference void ratio of a soil at the maximum density
e_B	Eccentricity parallel with B , M_B/Q , ft
e_W	Eccentricity parallel with W , M_W/Q , ft
f_n	Negative skin friction, ksf
f_{ni}	Mobilized negative skin friction of pile element i , ksf
f_s	Skin friction, ksf
f_{si}	Skin friction of pile element i , ksf
f'_c	Concrete strength, psi
f'_{ys}	Steel yield strength, psi
f_s^-	Full mobilized skin friction, ksf
h	Height of hammer fall, ft
h_v	Vane height, inch

Symbol	Description
k	Constant relating elastic soil modulus with depth $E_s = kz$, kips/ft ³ Term preventing unlimited increase in bearing capacity with increasing depth for Hanson method
k_c	Point correlation factor used in CPT B & G method
n	Number of piles in a group, number of pile elements
p_o	Internal pressure causing lift-off of dilatometer membrane, ksf
p_1	Internal pressure required to expand central point of the dilatometer membrane by 1.1 millimeters, ksf
p_L	Pressuremeter limit pressure, ksf
q	Bearing pressure on foundation, ksf
q_1	Soil pressure per inch of settlement, ksf
q_a	Allowable unit bearing capacity, ksf
q_b	Unit base resistance, ksf
q_{bu}	Unit ultimate end bearing resistance, ksf
q_c	Cone penetration resistance, ksf
q_{c1}	Average q_c over a distance of $L+0.7B$ to $L+4B$ below pile tip, Figure 5-21, ksf
q_{c2}	Average q_c over a distance L to $L-8B$ above pile tip, Figure 5-21, ksf
q_{cb1}	Average cone penetration resistance from footing base to $0.5B$ below base, ksf
q_{cb2}	Average cone penetration resistance from $0.5B$ to $1.5B$ below base, ksf
q_{ci}	Cone penetration resistance of depth increment i , ksf
\bar{q}_c	Equivalent cone penetration resistance from footing base to $1.5B$ below base, ksf
q_d	Design unit bearing pressure, ksf
q_{load}	Area pressure applied to soil supporting pile, ksf
q_{na}	Nominal unit allowable bearing capacity, ksf

Symbol	Description
q_r	Resultant applied pressure on foundation soil, R/BW, ksf
q_u	Ultimate unit bearing capacity, ksf
q_{ua}	Ultimate unit bearing capacity of axially loaded square or round footings with horizontal ground surface and base, kips
q_{ut}	Ultimate unit bearing capacity of upper dense sand, ksf
$q_{a,1}$	Allowable unit bearing capacity for 1 inch of settlement, ksf
$q_{u,b}$	Ultimate unit bearing capacity on a very thick bed of the bottom soft clay layer, ksf
$q_{u,p}$	Ultimate unit bearing capacity of plate, ksf
q_ℓ	Limiting stress for Meyerhof method $N_{qp}\tan\phi'$, ksf
q'_u	Net ultimate bearing capacity, $q_u - \gamma_D \cdot D$, ksf
r_γ	Reduction factor, $1 - 0.25\log(B/6)$
s	Spacing between piles, ft
u_w	Pore water pressure, ksf
y_a	Allowable lateral deflection, inch
y_o	Lateral groundline deflection, inch
z	Depth, ft
A	Cross-section area of drilled shaft or pile, ft^2
A_b	Area of tip or base, ft^2
A_{bp}	Area of base resisting pullout force, ft^2
A_e	Effective area of foundation B'W', ft^2
A_{si}	Perimeter area of pile element i , $C_{si} \cdot \Delta L$
A_{st}	Area of steel, $inch^2$
B	Least lateral dimension of a foundation or pile diameter, ft
B_b	Base diameter, ft

Symbol	Description
B_{dia}	Diameter of circular footing, ft
B_p	Diameter or width of the plate, ft
B_r	Horizontal distance beneath center of strip footing to location of outermost rod in reinforced soil, ft
B_s	Diameter or width of pile or shaft, ft
B'	Effective foundation width, $B - 2e_B$, ft
C_f	Correction factor for K when $\delta \neq \phi'$
C_g	Circumference of pile group, minimum length of line that can enclose pile group, ft
C_{ua}	Average undrained shear strength of cohesive soil in which the group is placed, ksf
C_{ub}	Average undrained shear strength of cohesive soil below the tip to a depth $2B_b$ below the tip, ksf
C_{um}	Mean undrained shear strength along pile length, ksf
C_{ov}	Overburden pressure adjustment $(\sigma_o/\sigma'_v)^{0.5}$
C_s	Circumference of drilled shaft or pile, ft
C_{si}	Circumference of drilled shaft or pile element i , ft
C_u	Undrained cohesion, ksf
$C_{u,lower}$	Undrained shear strength of the soft lower clay, ksf
$C_{u,upper}$	Undrained shear strength of the stiff upper clay, ksf
C_z	Pile Perimeter at depth z , ft
C_{ER}	Rod energy correction factor
C_L	Perimeter of the pile tip, ft
C_N	Overburden correction factor
CPT	Cone penetration test
D	Depth of the foundation base below ground surface, ft

Symbol	Description
D_c	Critical depth where increase in stress from structure is 10 percent of the vertical soil stress beneath the foundation, ft
D_e	Equivalent embedment depth using CPT procedure for estimating bearing capacity, ft
D_r	Relative density, percent
D_R	Relative density, fraction
D_{GWT}	Depth below ground surface to groundwater, ft
E_g	Efficiency of pile group
E_h	Hammer efficiency
E_p	Young's modulus of pile, ksf (kips/inch ²)
E_s	Elastic soil modulus, ksf
E_{s1}	Lateral modulus of soil subgrade reaction, ksf
F_r	Reduction factor for drilled shaft unit end bearing capacity
FS	Factor of safety
G	Specific gravity
G_i	Initial shear modulus, ksf
G_s	Shear modulus, ksf
H	Depth of shear zone beneath base of foundation, ft
H_b	Vertical distance from the shaft base in a group to the top of the weak layer, ft
H_r	Height of vertical reinforcement rods placed in soil supporting a strip foundation, ft
H_t	Depth below footing base to weak stratum or soft clay, ft
I_c	Moment of inertia of concrete section, ft ⁴
I_p	Moment of inertia of pile, ft ⁴
I_r	Rigidity index

Symbol	Description
I_{rr}	Reduced rigidity index
I_{st}	Moment of inertia of steel section, ft^4
I_D	Material deposit index of dilatometer test
K	Lateral earth pressure coefficient
K_o	Coefficient of earth pressure at rest
K_p	Rankine coefficient of passive pressure, $\tan^2(45 + \frac{\phi}{2})$ or $\frac{1 + \sin\phi}{1 - \sin\phi}$
K_{ps}	Punching shear coefficient
K_v	Constant depending on dimensions and shape of the vane, ft^3
K_D	Horizontal stress index of dilatometer test
L	Embedded length of deep foundation, ft
L_C	Critical depth at which increasing pile lengths provide no increase in end bearing resistance for Meyerhof's method, ft
L_c	Critical length between long and short pile, ft
L_{cs}	Critical length between short and intermediate pile, ft
L_{cl}	Critical length between intermediate and long pile, ft
L_{clay}	Length of pile in clay, ft
L_n	Length to neutral point n, ft
L_{sand}	Length of pile in sand, ft
L_{sh}	Horizontal length of shear zone at the foundation depth, ft
M_a	Applied bending moment on pile butt (top) in clockwise direction, kips-ft
M_y	Ultimate resisting bending moment of entire pile cross-section, kips-ft
M_B	Bending moment parallel with B, kips-ft
M_W	Bending moment parallel with W, kips-ft
N_c	Dimensionless bearing capacity related with cohesion

Symbol	Description
N_{cp}	Pile dimensionless bearing capacity related with cohesion
N_k	Cone factor relating undrained cohesion with cone penetration resistance, often varies from 14 to 20
N_n	Standard penetration resistance correlated to n percent energy, blows/foot
N_p	Relationship between shear modulus and undrained cohesion used in pressuremeter test, $1 + \ln(G_s/C_u)$
N_q	Dimensionless bearing capacity factor related with surcharge
N_{qp}	Pile dimensionless bearing capacity factor related with surcharge
N_{SPT}	Average blow per foot in the soil produced by a 140 pound hammer falling 30 inches to drive a standard sampler (1.42" I.D., 2.00" O.D.) one foot
N_{60}	Penetration resistance normalized to an effective energy delivered to the drill rod at 60 percent of theoretical free-fall energy, blows/foot
N_{70}	Penetration resistance normalized to an effective energy delivered to the drill rod at 70 percent of theoretical free-fall energy, blows/foot
N_γ	Dimensionless bearing capacity factor related with soil weight in the failure wedge
$N_{\gamma p}$	Pile dimensionless bearing capacity factor related with soil weight in the failure wedge
N_ϕ	$\tan^2 \left[45 + \frac{\phi}{2} \right]$
OCR	Overconsolidation ratio
P	Pullout load, kips
PI	Plasticity index, percent
P_{max}	Maximum tensile force in shaft, kips
P_{nu}	Pullout skin resistance force, kips
$P_{nu i}$	Pullout skin resistance for pile element i, kips
P_u	Ultimate pullout resistance, kips

Symbol	Description
Q	Vertical load on foundation, kips
Q_a	Allowable bearing capacity force, kips
Q_b	Base resistance force, kips
Q_{bu}	Base resistance capacity, kips
Q_{bur}	Ultimate base resistance of upper portion of underream, kips (pounds)
Q_d	Design bearing force, kips
Q_e	Applied load in elastic range, kips
Q_s	Soil-shaft side friction resistance, kips
Q_{su}	Soil-shaft side friction resistance capacity or uplift thrust, kips
Q_{sub}	Ultimate soil shear resistance of cylinder of diameter B_b and length down to underream, kips (pounds)
Q_{sud}	Downdrag, kips (pounds)
Q_{sui}	Ultimate skin friction resistance of pile element i , ksf
Q_{sur}	Ultimate skin resistance, kips (pounds)
Q_u	Ultimate bearing capacity force, kips
Q_{ug}	Ultimate load capacity of pile group, kips
$Q_{ug,lower}$	Bearing capacity of base at top of lower (weak) soil, kips
$Q_{ug,upper}$	Bearing capacity in the upper soil if the softer lower soil were not present, kips
Q_{up}	Uplift force on foundation, kips
Q_w	Working load, kips (pounds)
Q_{DL}	Dead load of structure, kips (pounds)
R	Resultant load on foundation, $(Q^2 + T^2)^{0.5}$
R_{bc}	Scale reduction factor for end bearing capacity in clay
R_{bs}	Scale reduction factor for end bearing capacity in sand

Symbol	Description
R_d	Ratio of equivalent embedment depth to footing width, D_e/B
R_e	Eccentricity adjustment factor
R_k	Bearing ratio using CPT procedure for estimating bearing capacity
R_v	Strength reduction factor of vane shear test
S	Average penetration in inches per blow for the last 5 to 10 blows for drop hammers and 10 to 20 blows for other hammers
S_r	Spacing between vertical reinforcement rods in soil, ft
S_s	Shape factor, assume 1.000
S_u	Depth of scour, ft
SPT	Standard penetration test
T	Horizontal (lateral) load on foundation, kips
T_a	Allowable lateral load capacity, kips
T_u	Lateral load capacity, $T_{us} + T_{up}$, kips
T_{ug}	Lateral load capacity of pile group, kips
T_{ul}	Ultimate lateral load capacity of long pile in cohesionless soil, kips
T_{up}	Lateral load pile capacity, kips
T_{us}	Lateral load soil capacity, kips
T_v	Torque of the vane test, kips-ft
W	Lateral length of a foundation, ft
W_p	Pile weight or pile weight including pile cap, driving shoe, capblock and anvil for double-acting steam hammers, kips
W_r	Weight of striking parts of ram, kips
W'_T	Total effective weight of soil and foundation resisting uplift, kips
W'	Effective lateral length of a foundation, $W - 2e_w$
Z	Section modulus I_p/c , ft^3

Symbol	Description
Z_a	Depth of the active zone for heave, ft
Z_c	Concrete section modulus, ft ³
Z_{st}	Steel section modulus, ft ³
α_a	Adhesion factor
α_f	Dimensionless pile depth-width relationship factor
β	Angle of ground slope, deg
β_f	Lateral earth pressure and friction angle factor
γ	Wet unit soil weight, lbs/ft ³
γ_c	Moist unit weight of weak clay, kips/ft ³
γ_{conc}	Density concrete grout, kips/ft ³
γ_d	Dry density, kips/ft ³
γ_p	Pile density, kips/ft ³
γ_s	Unit wet weight of sand, kips/ ³
γ_{sand}	Unit wet weight of the upper dense sand, kips/ft ³
γ_w	Unit weight of water, 0.0625 kips/ft ³
γ_D	Unit wet weight of surcharge soil within depth D, kips/ft ³
γ_H	Wet unit weight of subsurface soil, kips/ft ³
γ_{HSUB}	Submerged unit weight of subsurface soil, $\gamma_H - \gamma_w$, kips/ft ³
γ'	Effective wet unit weight of soil, $\gamma - u_w$, kips/ft ³
γ'_b	Effective wet unit weight of soil beneath base, kips/ft ³
γ'_c	Effective wet unit weight of clay, kips/ft ³
γ'_s	Effective wet unit weight of sand, kips/ft ³
γ'_D	Effective unit weight of soil from ground surface to foundation depth, kips/ft ³

Symbol	Description
γ'_H	Effective unit weight beneath base of foundation to depth $D + H$ below ground surface, kips/ft ³
γ'_L	Effective wet unit weight of soil along shaft length L , kips/ft ³
Δ	Differential movement within span length L , ft
ΔL	Pile increment, ft
δ	Angle of base tilt, deg
δ_a	Soil-shaft effective friction angle, deg
ζ_c	Dimensionless correction factor related with cohesion accounting for foundation geometry and soil type
ζ_{cs}	Dimensionless correction factor related with cohesion and shape
ζ_{ci}	Dimensionless correction factor related with cohesion and inclined loading
ζ_{cd}	Dimensionless correction factor related with cohesion and foundation depth
$\zeta_{c\beta}$	Dimensionless correction factor related with cohesion and ground slope
$\zeta_{c\delta}$	Dimensionless correction factor related with cohesion and base tilt
ζ_{cp}	As above except for piles
ζ_γ	Dimensionless correction factor related with soil weight in the failure wedge (repeat as above for factors s , i , d , β and δ)
$\zeta_{\gamma p}$	As above except for piles
ζ_q	Dimensionless correction factor related with surcharge (repeat as above for factors s , i , d , β and δ)
ζ_{qp}	As above except for piles
θ	Angle of resultant load with vertical axis, $\cos^{-1} \left[\frac{Q}{R} \right]$
λ	Lambda correlation factor for skin resistance of Vijayvergiya & Focht method
ρ	Settlement, inch

Symbol	Description
ρ_b	Base displacement, inch
ρ_{bu}	Ultimate base displacement, inch
ρ_e	Elastic pile settlement, inch
ρ_i	Immediate plate settlement, inch
ρ_u	Ultimate pile settlement, inch
ρ_z	Vertical displacement at depth z , ft
σ'_d	Effective soil or surcharge pressure at foundation depth D , $\gamma'_D D$, ksf
σ_{ho}	Total horizontal in situ stress, ksf
σ'_i	Effective vertical stress in soil in at shaft (pile) element i , ksf
σ'_m	Mean effective vertical stress between the ground surface and pile tip, ksf
σ_n	Normal stress on slip path, ksf
σ_o	Reference overburden pressure, 2 ksf
σ'_p	Maximum past pressure in soil, ksf
σ'_v	Effective vertical stress, ksf
σ_{vc}	Total vertical pressure in soil including pressure from structure loads, ksf
σ'_{vc}	Effective total vertical pressure in soil including pressure from structure loads, ksf
σ_{vo}	Vertical overburden pressure, ksf
σ'_{vo}	Effective vertical overburden pressure, ksf
σ'_z	Effective overburden pressure at the center of depth z , $0 < z \leq L$, ksf
σ'_L	Effective soil vertical overburden pressure at pile base, $\gamma' \cdot L$, ksf
$\sigma'_{L/2}$	Effective stress at half the pile length, ksf
τ	Shear stress, ksf (psf)
τ_{max}	Shear stress at failure, ksf (psf)

Symbol	Description
τ_s	Soil shear strength, ksf
τ_u	Field vane undrained shear strength, ksf
ν_s	Poisson's ratio for soil
ϕ	Angle of internal friction of soil, deg
ϕ_{sand}	Angle of internal friction of upper dense sand, deg
ϕ'	Effective angle of internal friction of soil, deg
ϕ_a	Friction angle between foundation base and soil, deg
ϕ_g	Friction angle of granular material, deg
ψ	Angle of shear zone failure with respect to foundation base, Figure 1-3, $45 + \phi'/2$, deg
ω	Angle of pile taper from vertical, deg